

19990423 027

AB-28 - Paper

Occulomotor Analysis as an Indicator of Perceptual Performance

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Human visual system plays a crucial role in the processes of orientation in the surrounding world. Its proper functioning is a necessary precondition for every pilot. During the assessment of visual functioning a psychologist has to evaluate the abilities of visual processes which determine the efficient extraction of information from visual modality, especially in the situations which require performing several tasks in parallel. The mechanism of attention, however, is a functional structure, which is responsible not only for visual perception. In this research the processes of attention are conceptualized similarly as in the theories of Michael Posner. The notion of attention itself in those theories is close to the position of William James, who defined the attention in the following way (quoted also by Posner):

"Everybody knows what attention is. It is engagement of the mind in a clear and active way by something which appears to be one of several objects accessible at the same time or lines of thoughts". Posner distinguishes between broad and narrow understanding of attention. In a narrow notion, attention is a selection mechanism which operates on the incoming sensory information. Such a position is represented by a number of researchers in visual attention, among them A. Allport (1989) and A. Van der Heijden (1992). Attention understood broadly is rather "...a system for providing priority for motor acts, consciousness and memory" (Posner, 1994, p. 7398), see also (Posner, 1980; 1994). The aim of the methods proposed here is the assessment of the accuracy of functioning of visual attention, thus we focus only on those mechanisms, which control the scope of a visual field, and the processes of searching for and receiving visual information.

According to Posner (1994) at this point it is not possible to formulate a general theory of how the attention system works, nevertheless if we limit the scope of the theory to apply only to visual attention, the task becomes more feasible. The phenomenon of attention cannot be however reduced to a system of visual perception control, because it is a system that synchronizes the entire cognitive activity of a human being. Thus, even though the procedures presented here aim mainly at the analysis of visual attention functioning, it is important to remember, that it is only one aspect, a convenient perspective rather than an isolated and independent mechanism.

Processes of attention shifting are prior to the perception of a stimulus. Attention shifting precedes shifting of gaze to the new object as well as perceiving it in a conscious way. The moment of conscious perception of an object Posner calls a detection. Attention can be directed in an overt or in a covert manner. In the first case, attention shifting manifests itself as a movement of an eye or of the head, in the second case there is only an increase in readiness to react to an object which is to appear in an expected localisation. Therefore the direction of the gaze is not equated with the direction of attention.

Attention shifting can be directed intentionally or nonintentionally. In the first case, a subject searches for a necessary information in the surrounding space. Attention is directed according to an assumed strategy. The direction of attention can be also changed by the appearance of a new object in a visual field. Thus attention can be captured by a new stimulus. Posner (1980) originally described those phenomena as "location of attention direction control", however now he rather accepts, following J. Jonides, that there are two, relatively independent subsystems of attention (Posner, 1994). One of the goals of our work is to support the view that the mechanism of intentional direction of attention is not an independent entity but that it can be viewed as a function of the general mechanism which directs the whole ongoing activity of a human being.

The testing procedures that we propose here are designed to investigate the temporal characteristics of attention

disengagement as well as the ability to use the information given by passing it through the central attention mechanism or by providing information before, to activate the stimulus driven way of attention orienting.

The investigation of attention disengagement is based on the gap effect observed by Saslow. The task of a subject is to look at the monitor, where a central fixation point was displayed, and to shift the gaze onto new stimuli appearing on the screen. On some trials (the gap paradigm) the central fixation point is removed 200 ms before the stimulus appears. In the remaining trials (overlap paradigm) the central fixation point remains visible all the time.

If the mechanism of attention disengagement functions properly, then the reaction time should be shorter in the gap paradigm. Thus it should be 120-150 ms on average, while the reaction time in the overlap paradigm should be 180-200 ms. Moreover, in the gap paradigm the distribution of the reaction times should be bimodal, with the peaks at 90-100 ms and at 130-140 ms. The distribution of reaction times in the overlap paradigm should be approximately normal. Actually, the most worrisome situation is when the distribution is bimodal with an additional peak at 90-100 ms.

The design of the test tasks is presented in Figure 1.

The second series of tasks assumes manipulation of the mechanisms of attention direction. The operationalization of the automatic orientation mechanism is based on its functioning in the peripheral visual field. In classical experiments, originated by J. Jonides in the '70s (see Posner, 1980), in order for this mechanism to be activated, subjects were presented briefly with an additional stimulus in the localization to which attention was to be directed. In the research by C. Folk et al. (Folk et al., 1992) four symmetrically positioned squares were continuously shown on the computer screen. In one of them a stimulus was to be presented. 100 ms before the appearance of the actual stimulus, one of the squares was for a brief times surrounded by flashing points (figure 2).

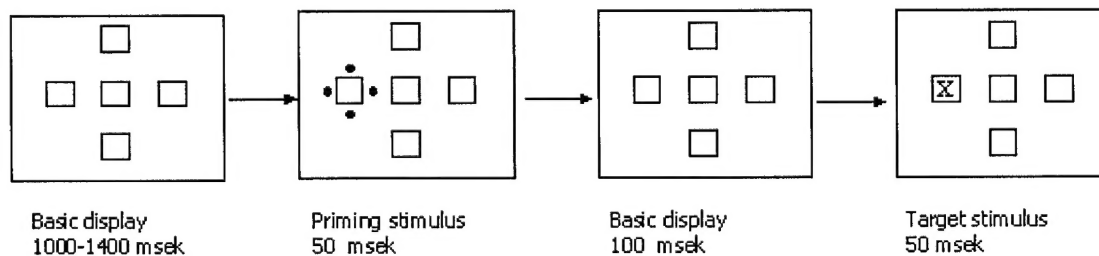


fig. 2. Task engaging stimulus-driven attention orienting adopted from Folk et al. (1992)

Other researchers used a similar design, substituting the points by brightening one of the squares (Muller, Rabbitt, 1989; Posner, Raichle, 1994). The procedure has been modified by S. Yantis and A. Hillstrom (1994). In order to distinguish the effect of the novelty of a stimulus from the effect of change in brightness, instead of brightening of the elements on the screen they changed the structure of the background in the appropriate position.

Since the activation time of the orientation mechanism is relatively short (Muller, Rabbitt, 1989) its effect diminished rapidly, when the gap between the preceding and the actual stimulus increased above 200 ms). The activation of the detection mechanism, which directs attention intentionally, is based on the presentation of a directing stimulus within the central visual field in such a way as to engage in its recognition higher cognitive structures.

A classical procedure was proposed in the 70's by J. Jonides (see Posner, 1980). The procedure requires a subject to focus on a point presented in the middle of a screen. Then, in the fixation point a symbolic element appeared (usually an arrow) which pointed the direction in which a stimulus was to be presented. Usually the arrow appeared only for a short time (most often 50 ms.), after which there followed a certain, predetermined pause and then the actual test stimulus. The length of the pause, similarly as in the case of operationalization of the orientation mechanism, is called a stimulus onset asynchrony (SOA).

An example of the utilization of the procedure belonging to the first group can be found in S. Yantis and J. Jonides (1990):

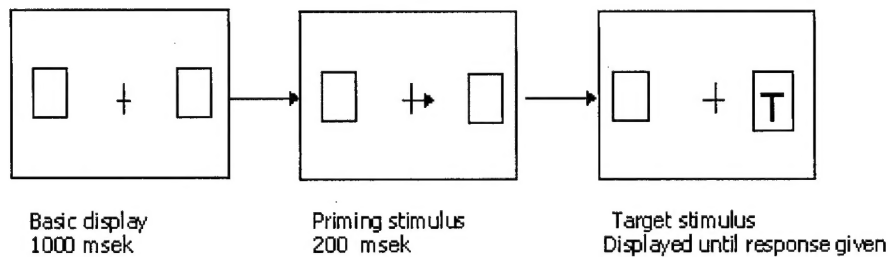
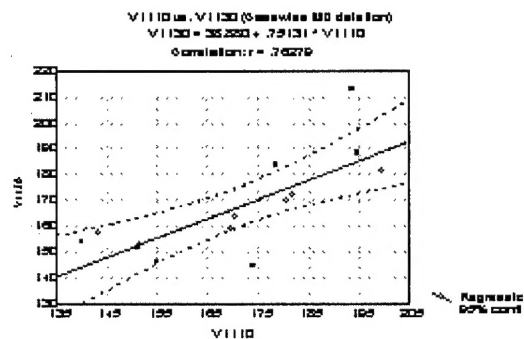


Fig. 3. Procedure in which intentional attention shifting was manipulated (Based on: Yantis & Jonides, 1990). An arrow, presented centrally, directs attention to the right.

In the schema presented in Figure 6, attention has been directed by an arrow presented in a central position on the screen. The procedure takes advantage of two features which are characteristic for the detection mechanism. First, the information was presented in the centre of the visual field, which allowed for its conscious processing. Second, a simple symbolic element was used (an arrow), the interpretation of which requires the operation of higher cognitive structures. As a reference point, allowing assessing the effectiveness of the manipulation of attention, an earlier procedure was used, based on the exposition in an overlap paradigm.

The experimental data, gathered so far allowed to determine the stability of the oculographic measurement procedures in the gap paradigm and in the overlap paradigm. The results are presented in the figures below:

Overlap



Gap

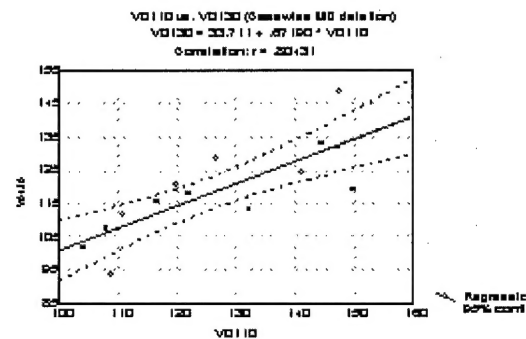


Fig. 4. Correlations of reaction time in the first and second measurement

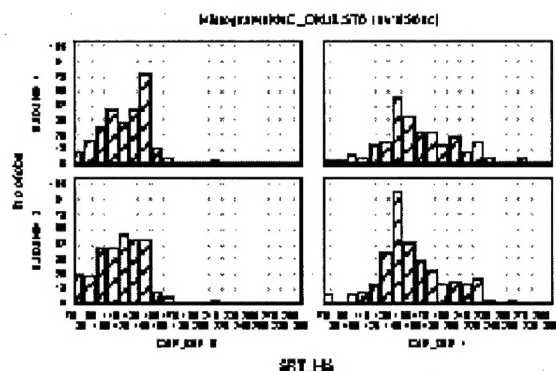


Fig. 5. The similarity of the reaction time distributions for the first and second measurement.

At the same time it was established that the investigation of the oculomotor reaction times gives results which are qualitatively different than the investigation based only on the recording of the motor reaction of the hand. When both aspects of the reaction time were recorded parallelly, their correlation, although statistically significant, have been definitely too low for using one of these variables as an estimator for the other. The results are presented in the figure below.

Summarising what has been presented above, it can be said that the construction of the tests based on a dynamical investigation of attention processes is a new approach, and a number of validating research have to be conducted before they can be used instead of psychometric methods that are currently available. Their advantage rests in the fact that they refer to most recent constructs of the theory of attention. Oculography may become an important tool in the assessment of the effectiveness of the cognitive processes in humans.

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